UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

| | |
|---|---|
| REPORT SECURITY CLASSIFICATION<br>UNCLASSIFIED | 1b. RESTRICTIVE MARKINGS |
| 2a. SECURITY CLASSIFICATION AUTHORITY | 3. DISTRIBUTION/AVAILABILITY OF REPORT<br>Approved for public release;<br>distribution is unlimited. |
| 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE | |
| 4. PERFORMING ORGANIZATION REPORT NUMBER(S)<br>TR 88-06 | 5. MONITORING ORGANIZATION REPORT NUMBER(S) |
| 6a. NAME OF PERFORMING ORGANIZATION<br>1. NAVENVPREDRSCHFAC<br>2. Science Applics Intnl Corp<br>6b. OFFICE SYMBOL (If applicable) | 7a. NAME OF MONITORING ORGANIZATION |
| 6c. ADDRESS (City, State, and ZIP Code)<br>1. Monterey, CA 93943-5006<br>2. Monterey, CA 93940 | 7b. ADDRESS (City, State, and ZIP Code) |
| 8a. NAME OF FUNDING/SPONSORING ORGANIZATION<br>Commander, Naval Oceanography Command<br>8b. OFFICE SYMBOL (If applicable) | 9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER<br>N00228-84-D-3187 |
| 8c. ADDRESS (City, State, and ZIP Code)<br>Stennis Space Center, MS 39529-5000 | 10. SOURCE OF FUNDING NUMBERS |

| PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO. |
|---|---|---|---|
| | | | DN656794 |

11. TITLE (Include Security Classification)

Severe Weather Guide - Mediterranean Ports - 22. Venice (U)

PERSONAL AUTHOR(S) Perryman, Dennis C. (NAVENVPREDRSCHFAC)

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT (Year, Month, Day) | 15. PAGE COUNT |
|---|---|---|---|
| Final | FROM 9/13/84 TO 3/28/88 | 1988, August | 57 |

16. SUPPLEMENTARY NOTATION

Funding source: O&M,N-1

17. COSATI CODES

| FIELD | GROUP | SUB-GROUP |
|---|---|---|
| 04 | 02 | |
| | | |

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

Storm haven — Mediterranean meteorology
Venice port — Mediterranean oceanography

19. ABSTRACT (Continue on reverse if necessary and identify by block number)


This handbook for the port of Venice, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.


| | |
|---|---|
| DISTRIBUTION/AVAILABILITY OF ABSTRACT<br>☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS | 21. ABSTRACT SECURITY CLASSIFICATION<br>UNCLASSIFIED |
| 22a. NAME OF RESPONSIBLE INDIVIDUAL<br>Perryman, Dennis C. | 22b. TELEPHONE (Include Area Code) (408) 647-4709 — 22c. OFFICE SYMBOL O&M,N-1 |

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

AN (1) AD-A202 280
FG (2) 040200
FG (2) 080300
CI (3) (U)
CA (5) SCIENCE APPLICATIONS INTERNATIONAL CORP MONTEREY CA
TI (6) Severe Weather Guide - Mediterranean Ports - 22. Venice.
TC (8) (U)
DN (9) Final rept. 13 Sep 84-28 Mar 88,
AU (10) Perryman, Dennis C.
RD (11) Aug 1988
PG (12) 59
CT (15) N00228-84-D-3187
RN (18) NEPRF-TR-88-06
RC (20) Unclassified report
DE (23) *WEATHER, *PORTS, (FACILITIES), HANDBOOKS, HAZARDS, MEDITERRANEAN SEA, ADVERSE CONDITIONS, OCEANOGRAPHIC DATA, THUNDERSTORMS, WIND, VISIBILITY, METEOROLOGICAL DATA, OCEAN WAVES, ITALY.
DC (24) (U)
ID (25) WUDN656794, *Venice(Italy), *Severe weather.
IC (26) (U)
AB (27) This handbook for the port of Venice, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and appendix that provides oceanographic information. (fr)
AC (28) (U)
DL (33) 01
SE (34) F
CC (35) 417277

#

Naval Environmental Prediction Research Facility
Monterey, CA 93943-5006

Technical Report TR 88-06 August 1988

# SEVERE WEATHER GUIDE for MEDITERRANEAN PORTS:

# 22. VENICE

CONTENTS

## FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

W. L. SHUTT
Commander, U.S. Navy

## PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

| 1988 NO. | PORT |
|---|---|
| 1 | GAETA, ITALY |
| 2 | NAPLES, ITALY |
| 3 | CATANIA, ITALY |
| 4 | AUGUSTA BAY, ITALY |
| 5 | CAGLIARI, ITALY |
| 6 | LA MADDALENA, ITALY |
| 7 | MARSEILLE, FRANCE |
| 8 | TOULON, FRANCE |
| 9 | VILLEFRANCHE, FRANCE |
| 10 | MALAGA, SPAIN |
| 11 | NICE, FRANCE |
| 12 | CANNES, FRANCE |
| 13 | MONACO |
| 14 | ASHDOD, ISRAEL |
| 15 | HAIFA, ISRAEL |
| 16 | BARCELONA, SPAIN |
| 17 | PALMA, SPAIN |
| 18 | IBIZA, SPAIN |
| 19 | POLLENSA BAY, SPAIN |
| 20 | LIVORNO, ITALY |
| 21 | LA SPEZIA, ITALY |
| 22 | VENICE, ITALY |
| 23 | TRIESTE, ITALY |
| 24 | CARTAGENA, SPAIN |
| 25 | VALENCIA, SPAIN |

| 1989 | PORT |
|---|---|
| | SAN REMO, ITALY |
| | GENOA, ITALY |
| | PALERMO, ITALY |
| | MESSINA, ITALY |
| | TAORMINA, ITALY |
| | PORTO TORRES, ITALY |
| | BENIDORM, SPAIN |
| | TANGIER, MOROCCO |

| 1990 | PORT |
|---|---|
| | TARANTO, ITALY |
| | ROTA, SPAIN |
| | SOUDA BAY, CRETE |
| | PORT SAID, EGYPT |
| | ALEXANDRIA, EGYPT |
| | ALGIERS, ALGERIA |
| | TUNIS, TUNISIA |
| | GULF HAMMAMET, TUNISIA |
| | GULF OF GABES, TUNISIA |

| 1991 | PORT |
|---|---|
| | PIRAEUS, GREECE |
| | KALAMATA, GREECE |
| | THESSALONIKI, GREECE |
| | CORFU, GREECE |
| | KITHIRA, GREECE |
| | VALETTA, MALTA |
| | LARNACA, CYPRUS |

| 1992 | PORT |
|---|---|
| | ANTALYA, TURKEY |
| | ISKENDERUN, TURKEY |
| | IZMIR, TURKEY |
| | GOLCUK, TURKEY |
| | ISTANBUL, TURKEY |
| | GULF OF SOLLUM |
| | SPLIT, YUGOSLAVIA |
| | DUBROVNIK, YUGOSLAVIA |

# PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

**ROUTINE REPLY, ENDORSEMENT, TRANSMITTAL OR INFORMATION SHEET**

OPNAV 5216/158 (Rev. 7-78) — *A WINDOW ENVELOPE MAY BE USED*

SN 0107-LF-052-1691 — *Formerly NAVEXOS 3789*

CLASSIFICATION (*UNCLASSIFIED when detached from enclosures, unless otherwise indicated*)

UNCLASSIFIED

FROM (*Show telephone number in addition to address*)

Commanding Officer, Naval Environmental Prediction Research Facility, Monterey, CA 93943-5006 AV 878-4731

DATE

12 Oct 88

SUBJECT

NAVENVPREDRSCHFAC TECHNICAL REPORTS TR 88-06...09, SEVERE WEATHER GUIDE, MEDITERRANEAN PORTS (4 VOLUMES)

SERIAL OR FILE NO. 5600
NEPRF/SBB:dat
Ser 396

TO:

Distribution
(See Encl (1)-(4), pp Dist. 1-6)

REFERENCE

ENCLOSURE

(1) TR 88-06
(2) TR 88-07
(3) TR 88-08
(4) TR 88-09

(See listing by volume number and port title in remarks below)

VIA:

ENDORSEMENT ON

[X] FORWARDED [ ] RETURNED [ ] FOLLOW-UP, OR TRACER [ ] REQUEST [ ] SUBMIT [ ] CERTIFY [ ] MAIL [ ] FILE

| | GENERAL ADMINISTRATION |
|---|---|
| | FOR APPROPRIATE ACTION |
| | UNDER YOUR COGNIZANCE |
| X | INFORMATION & retention |
| | APPROVAL RECOMMENDED [ ] YES [ ] NO |
| | [ ] APPROVED [ ] DISAPPROVED |
| | COMMENT AND/OR CONCURRENCE |
| | CONCUR |
| | LOANED, RETURN BY: |
| | SIGN RECEIPT & RETURN |
| | REPLY TO THE ABOVE BY |
| | REFERENCE NOT RECEIVED |
| | SUBJECT DOCUMENT FORWARDED TO |
| | SUBJECT DOCUMENT RETURNED FOR: |
| | SUBJECT DOCUMENT HAS BEEN REQUESTED, AND WILL BE FORWARDED WHEN RECEIVED |
| | COPY OF THIS CORRESPONDENCE WITH YOUR REPLY |
| | ENCLOSURE NOT RECEIVED |
| | ENCLOSURE FORWARDED AS REQUESTED |
| | ENCLOSURE RETURNED FOR CORRECTION AS INDICATED |
| | CORRECTED ENCLOSURE AS REQUESTED |
| | REMOVE FROM DISTRIBUTION LIST |
| | REDUCE DISTRIBUTION AMOUNT TO |

| | CONTRACT ADMINISTRATION |
|---|---|
| | NAME & LOCATION OF SUPPLIER OF SUBJECT ITEMS |
| | SUBCONTRACT NO. OF SUBJECT ITEM |
| | APPROPRIATION SYMBOL, SUBHEAD, AND CHARGEABLE ACTIVITY |
| | SHIPPING AT GOVERNMENT EXPENSE [ ] YES [ ] NO |
| | A CERTIFICATE, VICE BILL OF LADING |
| | COPIES OF CHANGE ORDERS, AMENDMENT OR MODIFICATION |
| | CHANGE NOTICE TO SUPPLIER |
| | STATUS OF MATERIAL ON PURCHASE DOCUMENT |

| | PERSONNEL |
|---|---|
| | REPORTED TO THIS COMMAND: |
| | DETACHED FROM THIS COMMAND |
| | OTHER |

REMARKS (*Continue on reverse*)

1. Enclosures (1)-(4) are port studies 22-Venice, 23-Trieste, 24-Cartagena, and 25-Valencia, respectively.

2. These studies document causes and effects of hazardous weather conditions for the Mediterranean ports specified. They provide decision-making guidance for ship captains and contain information that will assist meteorologists in making operational forecasts.

3. These port studies are part of the individual, port-specific severe weather guides produced by NAVENVPREDRSCHFAC. More than fifty-five port studies are planned for production over the next five years.

SIGNATURE & TITLE

C. A. MOREN, By direction

COPY TO:

CLASSIFICATION (*UNCLASSIFIED when detached from enclosures, unless otherwise indicated*)

UNCLASSIFIED

RECORD OF CHANGES

| CHANGE NUMBER | DATE OF CHANGE | DATE ENTERED | PAGE NUMBER | ENTERED BY |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

# 1. GENERAL GUIDANCE

## 1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

### 1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

### 1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.
B. Cruise reports were reviewed.
C. Navy personnel with current or previous area experience were interviewed.
D. A preliminary report was developed which included questions on various local conditions in specific harbors.
E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.
F. The cumulative information was reviewed, combined, and condensed for harbor studies.

### 1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,
B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,
C. local wind wave conditions, and
D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

## 1.2 CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested pre-cautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

# 2. CAPTAIN'S SUMMARY

The city of Venice (Venezia) is located on the western side of the Gulf of Venice at the northwest end of the Adriatic Sea (Figure 2-1). Venice proper stands on a group of 122 islets close together in the middle of a large, shallow lagoon, Laguna Veneta. The city is about 1.5 n mi from the sea. Laguna Veneta is about 5 n mi wide and 20 n mi long and is separated from the sea by a chain of long, low, narrow, sandy islets. The only connection between Venice and the mainland is a road and rail bridge 3.5 n mi in length (FICEURLANT, 1987).

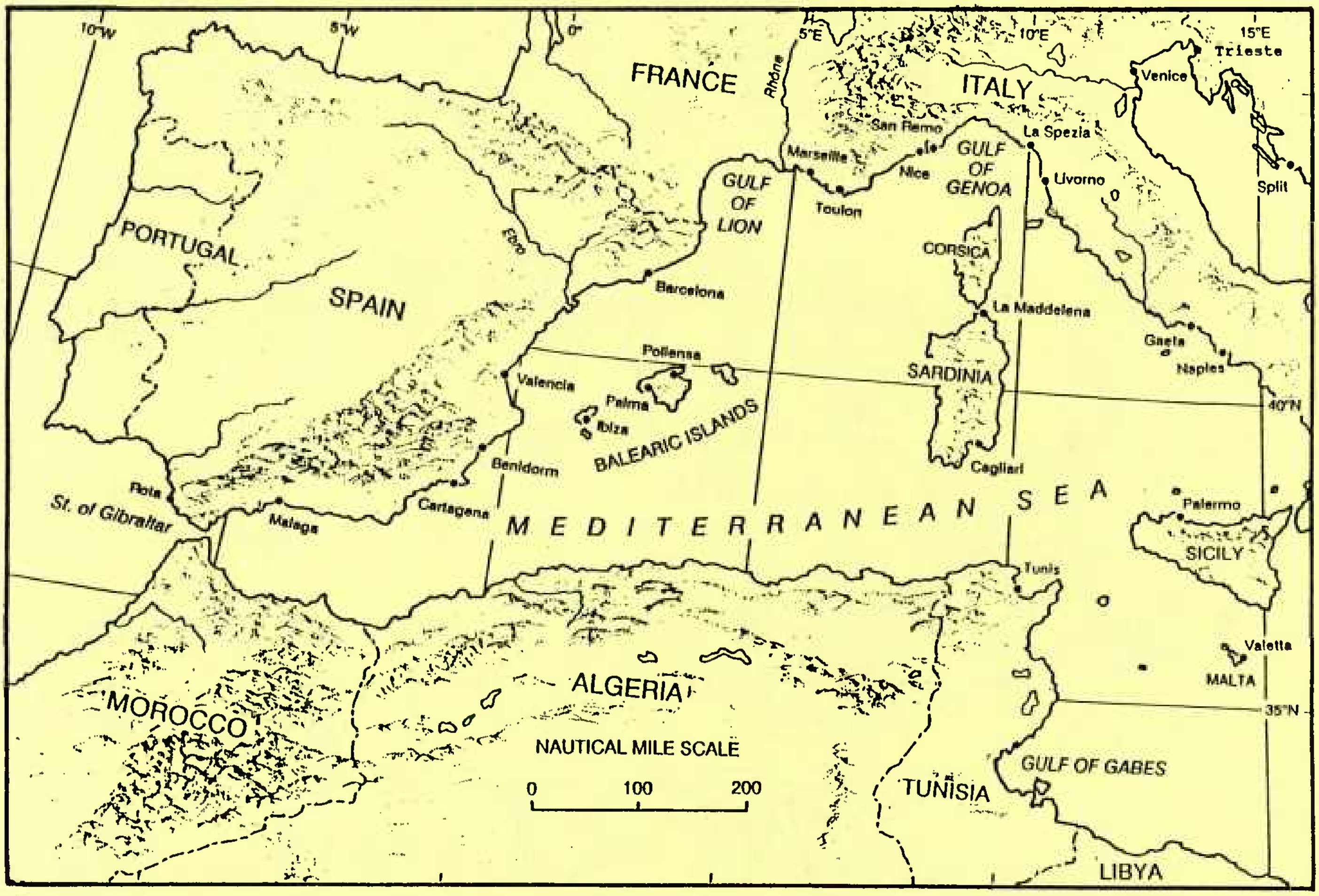


Figure 2-1. Western Mediterranean Sea.

The entrance to the Port of Venice is located at 45° 25'N 12° 26'E at Porto de Lido (Figure 2-2). Mean water depth of this channel is 28 ft. In an emergency, Malamocco Channel, to the south, can be used. Entrance draft is 45 ft but lowers to 32 ft in the canal used to get into Venice. The primary anchorage is located approximately 1 n mi due east of Porto de Lido. Depths range from 30 to 45 ft with good holding ground in mud and sand.

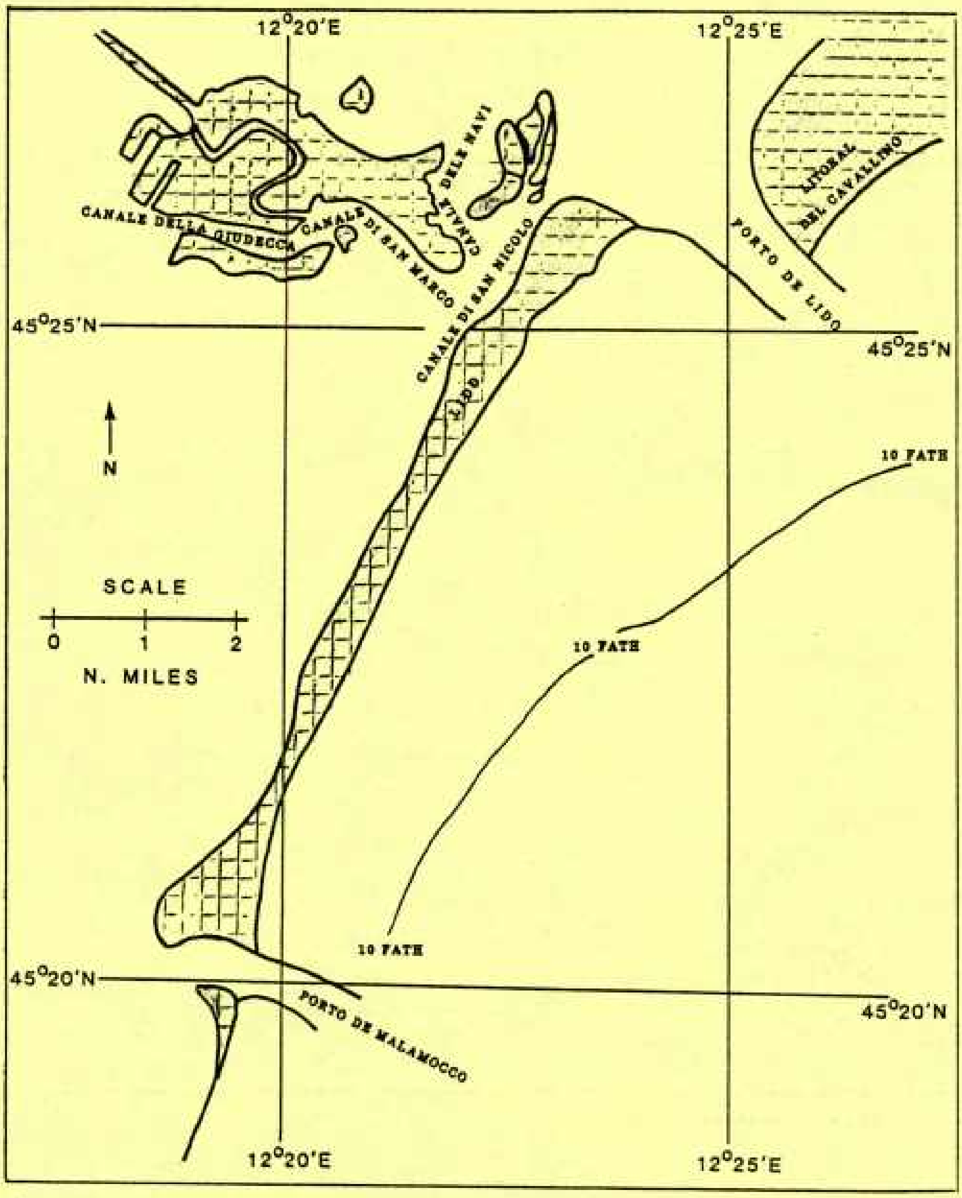


Figure 2-2. Venice Region.

The main berths and fleet landing are at Riva Dei Sete Martiri on the San Marco Canal (Figure 2-3). Other berths are available at buoys numbered 2, 3, and 4 4 just west of Riva Dei Sete Martiri and at buoys marked 7 and 8 in the canal between San Elena and La Certosa islands. If all these berths are taken or Venice is closed off for some reason (summit conference, etc), ships may berth at Porta Marghera, a commercial/ industrial port on the mainland 3.5 n mi northwest of Venice.

In the summer, water taxis are used to ferry personnel between the anchorage and fleet landing. Only authorized fleet landings should be used as most landings within Venice are private property. These taxis are seaworthy and have radar so boating can be carried out in foggy weather (as long as visibility is more than 1000 ft) and in relatively high seas (up to 6-7 ft). In winter, these taxis are usually laid up for maintenance and taxi shortages are common. The pilot station is located near the Malamocco Channel entrance and controls ship movements in the area from a 100 ft tower equipped with radar.

Tidal range in Venice is 4 ft (1.25 m) but water levels can change by as much as 7 ft (2.0 m) due to a combination of high tide, low atmospheric pressure and southeast winds which raises the water level and floods the city. Abnormally low water levels will occur with the reverse conditions. Local mariners watch the water level on the "dolphins," vertical timbers lashed together and used as moors. Rising water, when it should be lowering, is a signal of possible flood conditions. Note that during and after flooding,trash,

trash bags and seaweed float in the canals. This trash is especially a problem where it concentrates near seawalls, and can foul intakes.

A one kt north-to-south current exists off the coast of Venice, however, tidal currents of 3 to 5 kt exist within Laguna Veneta.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasion action scenarios for the Port of Venice are summarized in Table 2-1.

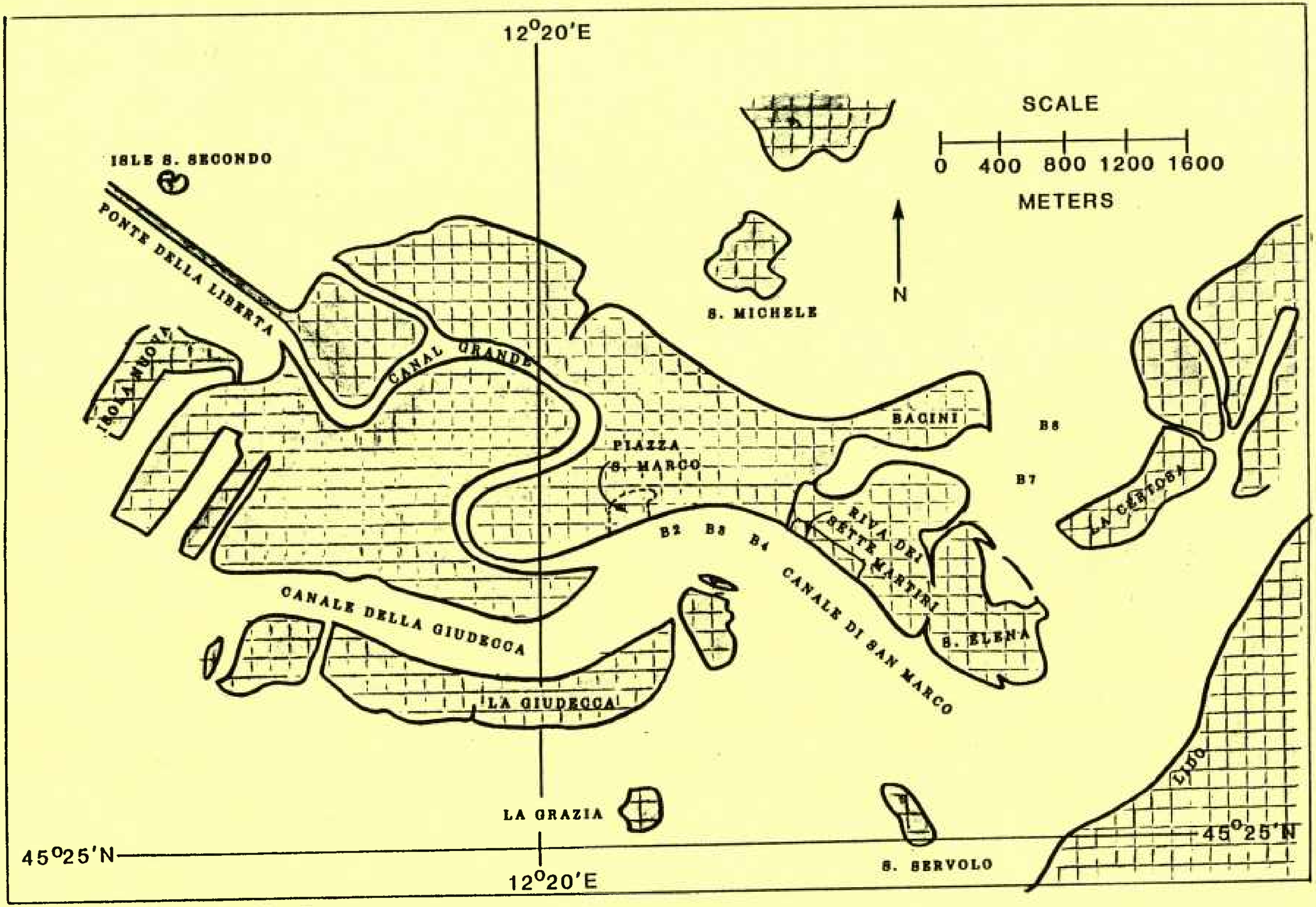


Figure 2-3. Port of Venice.

Table 2-1. Summary of hazardous environmental conditions for the Port of Venice, Italy

| HAZARDOUS CONDITION | INDICATORS OF POTENTIAL HAZARD | VESSEL LOCATION/ SITUATION AFFECTED | EFFECT - PRECAUTIONARY/EVASIVE ACTIONS |
|---|---|---|---|
| 1. ENE'ly winds - Bora<br>* Strong winds affecting the entire N. Adriatic.<br>* Occurs year-round - most common in cold season. Peak month is November.<br>* 35 kt gusting to 60 kt common in winter at Venice.<br>* Strongest during afternoon, weakest at sunrise and sunset. | Advance Warning<br>* Clouds atop the mountains to the north will sometimes precede onset of Bora winds.<br>* Bora can be expected after a 24 hr or so of southeasterly winds, often with rain.<br>* Strongest winds usually not at onset. | (1) Moored - inner harbor. | a. Winds, more than waves, will affect moored ships.<br>* Adding lines is most effective measure to take.<br>b. Wind chill factors can be hazardous in winter and early spring. |
| | | (2) Anchorage. | a. Winds with high waves (13 ft) will affect anchored ships.<br>* It is best to protect at sea during Bora episode.<br>* It is possible to limit waves substantially by maneuvering close to eastern coastline - north of Trieste only. South of Trieste is the Yugoslavian two-mile territorial limit. Caution: To the north of Trieste, there are mussel farms near shore. Consult latest charts.<br>b. Wind chill factors can be hazardous during winter and early spring. |
| | | (3) Arriving/Departing. | a. Winds and high waves (13 ft) will affect departures and arrivals.<br>* It is best to stay at sea if possible, rather than anchor on arrival.<br>* It is possible to limit waves substantially by maneuvering close to eastern coastline - north of Trieste only. South of Trieste is the Yugoslavian two-mile territorial limit. Caution: To the north of Trieste are mussel farms. Consult latest charts.<br>* On departure, note that waves in the lagoon will be minimal but increase significantly after entering the Adriatic.<br>b. Wind chill factors can be hazardous during winter and early spring. |
| | | (4) Small Boats | a. Local water taxis are seaworthy and can ferry personnel during Bora outbreaks where waves do not exceed 6-7 ft.<br>* Fleet landing is sheltered from high waves while anchorage is exposed.<br>b. Wind chill factors can be hazardous during winter and early spring. |

Table 2-1. (Continued)

| HAZARDOUS CONDITION | INDICATORS OF POTENTIAL HAZARD | VESSEL LOCATION/ SITUATION AFFECTED | EFFECT - PRECAUTIONARY/EVASIVE ACTIONS |
|---|---|---|---|
| 2. <u>S'ly winds</u> - Scirocco<br>* Usually cover the entire Adriatic.<br>* Winds are cool in winter, hot in summer.<br>* Occurs year-round, most common October through January.<br>* 30 kt gusting to 45 kt common at Venice. | <u>Advance Warning</u><br>* Onset much more gradual than Bora onset and winds not as intense.<br>* Low pressure center approaching from west or south will cause a Scirocco.<br>* Local water level will rise 1 or 2 hours prior to onset of winds and waves.<br>* Waves do not build gradually but come with onset of winds. | (1) <u>Moored - Inner harbor</u>. | a. <u>Scirocco often causes flooding in Venice as water levels in the lagoon rise</u>.<br>* Adding lines normally sufficient protection measure from winds.<br>* During and after flooding floating trash and debris can foul intakes, especially where it concentrates near seawalls. |
| | | (2) <u>Anchorage</u>. | a. <u>High waves (13 ft) can be expected at the anchorage</u>.<br>* It is better to protect at sea if possible than stay at anchorage.<br>* Closest protected harbor is Trieste which can afford protection from waves but not winds.<br>* Fog often accompanies Scirocco. Occasionally visibilities will be near zero during early morning hours between October and mid-April. |
| | | (3) <u>Arriving/Departing</u>. | a. <u>Departing and arriving during strong Scirocco difficult</u>.<br>* If arriving, it is best to stay at sea until conditions improve.<br>* On departure, note that waves in lagoon are minimal but increase sharply once entering the Adriatic.<br>* If flooding is occurring in Venice, departure can be complicated due to large amount of harbor traffic.<br>* Fog often accompanies Scirocco winds. Occasionally visibility will be near zero during early morning hours between October and mid-April. Harbor traffic ceases when visibility less than 1000 ft. |
| | | (4) <u>Small Boats</u>. | a. <u>Fleet landing is sheltered from high waves but high water levels may complicate loading</u>.<br>* Local water taxis are seaworthy and boating can continue in waves up to 6-7 ft.<br>* During flooding incidents, local taxis will be difficult to obtain as they will be used in emergency situations.<br>* Fog often accompanies Scirocco winds. Occasionally visibility will be near zero during early morning hours between October and mid-April. Harbor traffic ceases when visibility less than 1000 ft. |

## SEASONAL SUMMARY OF VENICE HAZARDOUS WEATHER CONDITIONS

(Much of this information is adapted from Brody and Nestor, 1980).

WINTER (November thru February):

* Bora winds occur year-round with November the peak month. Winds of force 28-40 kt (force 7 to 8) with higher gusts are not uncommon. Expect 13 ft (4 m) waves at the anchorage.
* Boras commonly last one or two days in winter.
* Below freezing temperatures combined with Bora winds cause hazardous wind chill factors.
* Strong southerly winds (Scirocco) occur in October through December and often cause flooding in Venice.
* Scirocco winds cause 13 ft (4 m) waves at anchorage.
* Early morning fog common in winter with 10 days per month of visibilities less than 1000 ft and often near zero.

SPRING (March thru May):

* Early spring similar to winter. Bora wind speeds normally 22 - 27 kt (force 6) in mid to late spring.
* Visibility in early spring same as in winter but starts improving by Mid-April.
* Thunderstorms, though infrequent, start occuring.

SUMMER (June thru September):

* Bora winds still possible but usually less than 25 kt.
* Thunderstorms more frequent but are normally short lived and isolated.
* West wind known locally as Garbin, occurs for short periods (up to 6 hours) in summer with maximum speeds of 40 kt.

AUTUMN (October):

* Short transition season as winter weather returns by end of month.
* Strong Sciroccos will occur in October.
* Fog and reduced visibilities return as month begins.
* Wind chill not a factor until late november.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and the Hazardous Weather Summary in Section 3.

## REFERENCES

Brody, L.R. and M.J.R. Nestor, 1980: Regional Forecasting Aids for the Mediterranean Basin, NAVENVPREDRSCHFAC Technical Report TR 80-10. Naval Environmental Prediction Research Facility, Monterey, California 93943-5006.

FICEURLANT, 1987: Port Directory for Venice, Italy (1986). Fleet Intelligence Center Europe and Atlantic, Norfolk, Virginia.

## 3. GENERAL INFORMATION

The information in this section is intended for fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of winds and weather and Table 3-2 presents a summary of hazards and actions by season.

### 3.1 Geographic Location

The city of Venice (Venezia) is located on the western side of the Gulf of Venice at the northwest end of the Adriatic Sea (Figure 3-1). Venice proper stands on a group of 122 islets close together in the middle of a large, shallow lagoon, Laguna Veneta. The city is about 1.5 n mi from the sea. Laguna Veneta is about 5 n mi wide and 20 n mi long and is separated from the sea by a chain of long, low, narrow, sandy islets. The only connection between Venice and the mainland is a road and rail bridge 3.5 n mi in length (FICEURLANT, 1987).

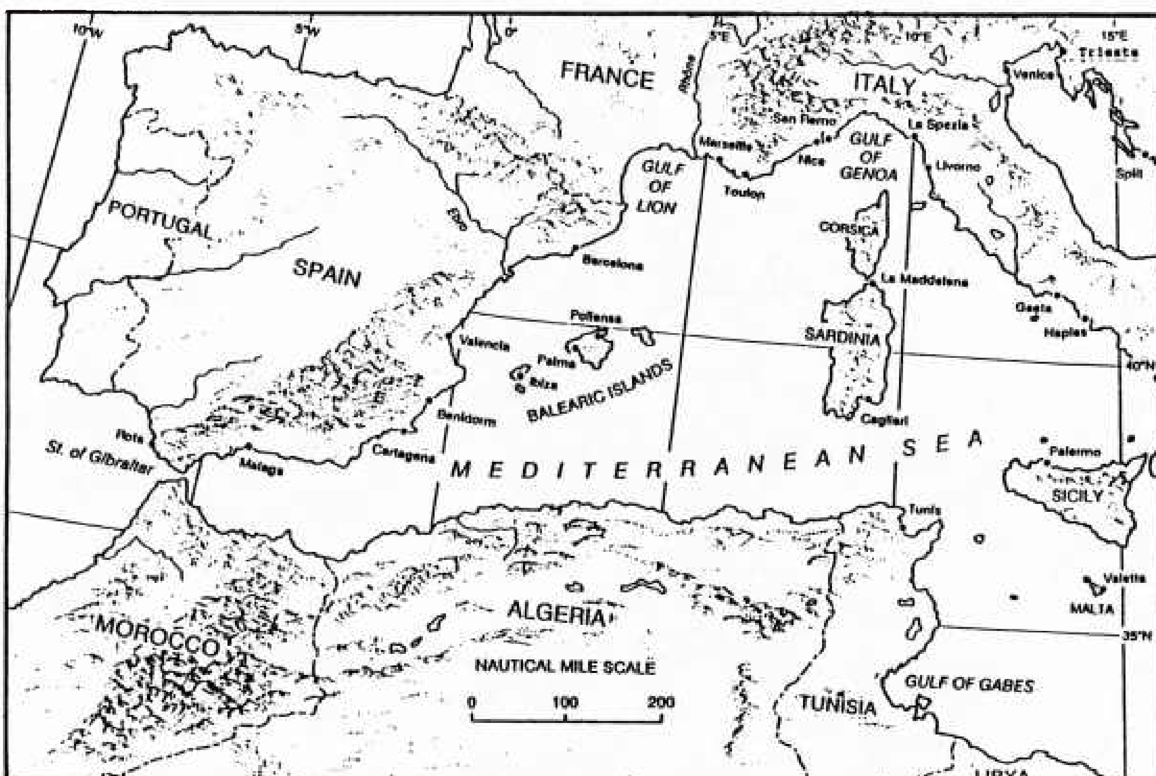


Figure 3-1. Western Mediterranean Sea.

The entrance to the Port of Venice is located at 45° 25'N 12° 26'E at Porto de Lido (Figure 3-2). Mean water depth of this channel is 28 ft. In an emergency, Malamocco Channel, to the south, can be used. Entrance draft is 45 ft but lowers to 32 ft in the canal used to get into Venice. The primary anchorage is located approximately 1 n mi due east of Porto de Lido. Depths range from 30 to 45 ft with good holding ground in mud and sand.

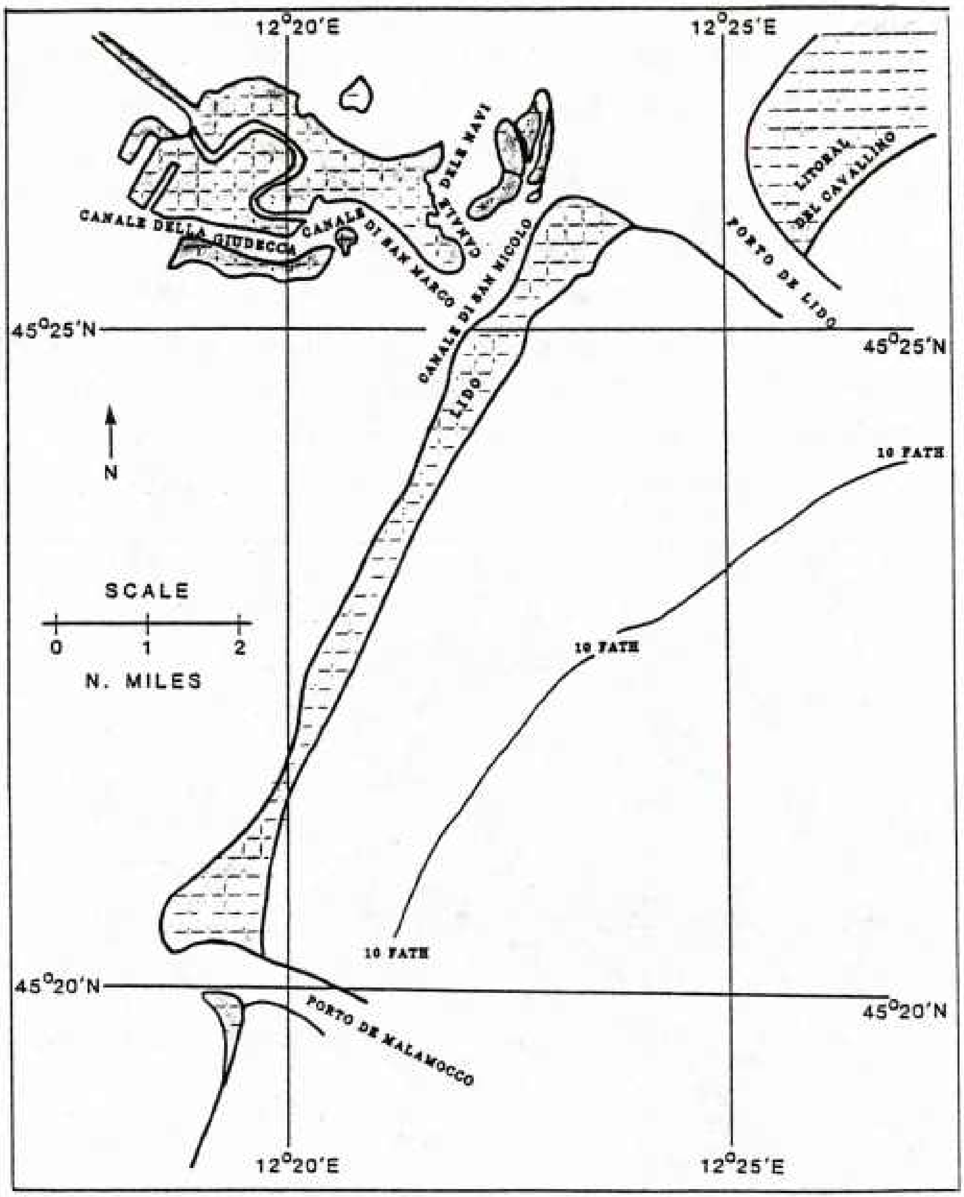


Figure 3-2. Venice Region.

The main berths and fleet landing are at Riva Dei Sete Martiri on the San Marco Canal (Figure 3-3). Other berths are available at buoys numbered 2, 3, and 4 just west of Riva Dei Sete Martiri and at buoys marked 7 and 8 in the canal between San Elena and La Certosa islands.

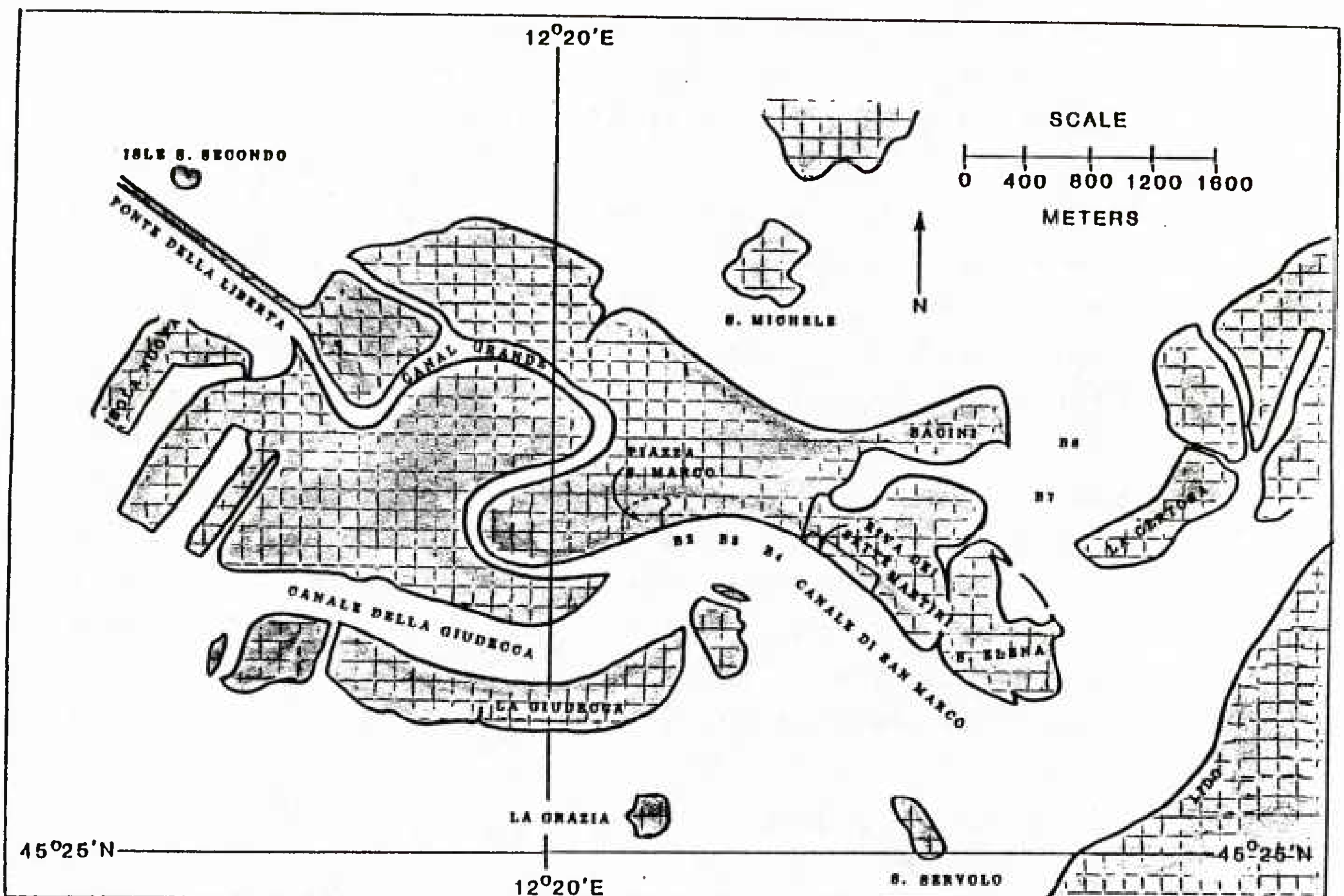


Figure 3-3. Port of Venice.

## 3.2 Qualitative Evaluation of the Port of Venice

The Port of Venice is in an area of frequent Bora wind and frequent Scirocco wind occurrences. The Bora is not as strong in Venice as it is in Trieste and the Scirocco is not as strong as it is in the southern Adriatic region.

Aside from the berths at Riva Dei Sete Martiri and at the buoys, additional berthing is available in Porta Marghera, a commercial/industrial port on the mainland 3.5 mi northwest of Venice.

In the summer, water taxis are used to ferry personnel between the anchorage and fleet landing. Only authorized fleet landings should be used as most landings within Venice are private property. These taxis are seaworthy and have radar so boating can be carried out in foggy weather (as long as visibility is more than 1000 ft) and in relatively high seas (up to 6-7 ft). In winter, these taxis are usually laid up for maintenance and taxi shortages are common. The pilot station is located near the Malamocco Channel entrance and controls ship movements in the area from a 100 ft tower equipped with radar.

## 3.3 Currents and Tides

There is a large counterclockwise current gyre in the center of the Adriatic Sea which sometimes breaks into two smaller gyres. In any case, the general current flow is northward along the eastern shores and southward along the western shores (Italian Oceanographic Institute, 1982). There is a one kt north-to-south current just off the coast of Venice.

Tidal currents within Laguna Veneta reach speeds of 3 to 5 kt.

Astronomical tide range in Venice is 4 ft (1.25 m) but water levels can change by as much as 7 ft (2.0 m) due to a combination of high tide, low atmospheric pressure and southeast winds which raises the water level and periodically floods the city. Abnormally low water levels will occur with the reverse conditions. Local mariners watch the water level on the "dolphins", vertical timbers lashed together and used as moors. Rising water, at a time when it should be lowering, will signal possible flooding. Note that during and after flooding, trash, plastic trash bags, and seaweed will often cause fouling of intakes, especially where it concentrates near seawalls.

## 3.4 Visibility

Visibility is generally poor from October to mid-April and is characterized by long periods of heavy fog. During this period it is normal to have 10 days of fog each month where visibility will be 1000 ft in the morning hours. Half of those days, the visibility will be near zero for periods of less than 3 hours in the early morning. When this occurs, harbor traffic comes to a halt.

Visibility between mid-April and the end of September is usually good. There are periods of reduced visibility, 2 to 5 n mi, due to haze.

During Bora wind episodes, visibility will normally improve greatly while during Scirocco winds,

visibility will usually lower as the wind brings in moist, fog-laden air.

## 3.5 Winds and Weather

Venice's climate is dominated by the Bora wind which can occur anytime during the year. However, the peak frequency occurs in the cold season (October - March). To a lesser extent, the Scirocco wind affects Venice but is not nearly as strong or as frequent as the Bora. Gulf of Genoa lows have an influence on weather in the northern Adriatic Sea as they either move toward Venice causing stormy weather with clouds and rain, or they move southeastward causing a pressure differential in the northern Adriatic Sea and trigger a Bora outbreak. Much of the following information is adapted from Brody and Nestor, 1980.

### 3.5.1 Bora

The Bora occurs when cold air accumulates over the Balkan Peninsula, especially Yugoslavia. When the depth of the cold air pool reaches the height of the mountain passes, the Bora will commence. There are two primary weather patterns associated with the Bora:

(1) Anticyclonic Pattern: A large high pressure center is present over Central Europe without a well defined low to the south.

(2) Cyclonic Pattern: A low pressure center is present in the southern Adriatic Sea or in the Ionian Sea.

In either case, the pressure is higher on the European side of the mountains and lower on the Mediterranean side.

The Bora is most common in the Adriatic Sea where it flows mainly from the northeast through gaps in the Dinaric Alps. One of these gaps is near Trieste and is known as the Trieste Gap. On occasion, the Bora can be very localized, extending only a few n mi offshore. At other times, the Bora will dominate the entire Adriatic Sea and, when the pressure differential is large enough, the Bora can extend as far south as Malta.

In the northern Adriatic, the wind direction associated with the Bora is generally northeasterly but can vary in local areas due to the terrain. The Bora at Trieste is east-northeasterly and these winds eventually affect Venice. It is more northerly further south and even northwesterly along Italy's southeast coast. The strongest winds occur along the eastern shore of the Adriatic from Trieste to the Albanian border. It is most intense to the north, decreasing somewhat moving southward. The greatest intensity of the Bora occurs where the mountain peaks are at least 2000 ft above sea level and not more than two or three n mi inland. Over the open water of the Adriatic, winds are usually less intense but gale force winds (30+ kt) are common. The frequency of the gale force Bora in the open sea is greater for the cyclonic type of pattern than for the anticyclonic pattern. During the cyclonic pattern, the strongest winds are usually found in the southern Adriatic.

Bora winds are most common during the cold season (October through March). In Venice, the highest

frequency of occurrence and strongest winds occur in November. In general, the frequency of gale force winds varies from less than one day per month in the summer to two or three days per month during winter months. The average duration of a continuous gale force Bora over the Adriatic is about 12 hours but the winds sometimes will last up to two days. The average duration of a Bora that reaches gale force some time during its history is 40 hours with a maximum duration of 5 days. At Venice the average duration of a gale force Bora varies from a few hours to two days in winter.

There is a noticeable diurnal variation at coastal Adriatic stations during Bora conditions. During the day, at stations along the western shore, the sea breeze enhances the onshore flow of the Bora which leads to a increase in the strength of the Bora between 1200L and 1800L. In Venice the winds are strongest at noon and weakest at sunrise and sunset. With the anticyclonic pattern, the Bora is basically a dry wind due to its katabatic nature. Clear skies and good visibilities are found in the lee of the mountains while thick clouds associated with upslope motions are found on the mountain crests. These clouds subsequently dissipate in the descending air on the lee side. With the cyclonic pattern, the Bora is often accompanied by low clouds and reduced visibilities associated with rain and/or drizzle. These conditions are more noticeable over the open water areas than along the coastal zone.

### 3.5.2 Scirocco

The Scirocco is a southeasterly to southwesterly wind over the Mediterranean originating over North Africa and sometimes affecting the Adriatic Sea area.

The Scirocco normally occurs within the warm sector of a cyclone passing either north or west of the region. These cyclones originate either over North Africa or south of the Alps, primarily in the Gulf of Genoa. Scirocco conditions occur in the latter case when the circulation extends far enough southward to draw air from the North African region. The onset of the Scirocco is more gradual than the onset of a Bora. It occurs more frequently in the southern part of the Adriatic with a decrease in frequency northward. Although the Scirocco is not as strong as the Bora, winds can reach gale force (30+ kt), especially in winter and spring. The average duration of continuous gale force winds during a Scirocco is 10 to 12 hours with rare occurrences as long as 36 hours. The maximum wind speed likely during a Scirocco is about 55 kt.

The Scirocco wind is dangerous for the city of Venice as it causes the water level to rise and flooding occurs. Sea level fluctuations within the lagoon, although not large, have caused extensive damage to the artistic and architectural treasures of Venice. Three ft of extra water above the expected astronomical high tide results in significant flooding (Robinson, et al, 1973). It is common to have rises of 1 to 2 ft, which can cause minor flooding.

Although Scirocco winds occur year-round the favored months are October through January. These winds usually last one or two days and often bring rain, (sometimes mixed with Saharan dust) or fog. Wave heights can reach 13 ft (4 m) at the anchorage.

### 3.5.3 Genoa Lows

Genoa Lows are low-pressure systems which develop to the south of the Alps in the region incorporating the Gulf of Genoa, Ligurian Sea, Po Valley, Gulf of Venice and northern Adriatic Sea. Although several factors are important in cyclogenesis, the development of the cyclone near the Gulf of Venice - as opposed to the west near the Gulf of Genoa - depends on the amount of cold air penetrating the Po Valley from the northeast. If there is little or no cold air entering the Po Valley, the low will probably form in the Gulf of Venice; otherwise, cyclogenesis will occur to the west.

Genoa cyclones usually remain stationary (or at least leave a residual trough) south of the Alps throughout their life history. If the lows do move, they generally follow one of two tracks. The first track, common for cyclones developing in the Gulf of Venice, is a northeasterly to north-northeasterly direction across the Alps. This track is associated with strong southwesterly flow aloft. In this case, Scirocco conditions are likely if the circulation of the low extends southward into North Africa, allowing air from the desert source to move northward. The second track, associated with a strong anticyclone over the Balkans, Turkey and the Black Sea is in a southwesterly direction from the Gulf of Genoa towards the Ionian Sea. In this case, a gale force Bora is extremely likely by the time the depression moves into the Ionian Sea.

## 3.6 Seasonal Summary of Hazardous Weather Conditions

The seasonal weather patterns in the Adriatic

Sea area are controlled to a large extent by the monsoonal behavior of the Eurasia land mass. During the winter, the Siberian High develops and extends southwestward towards the Balkans. Cold Bora winds are the usual result of this pattern. Stormy and unsettled weather is also common during the winter with a high frequency of lows moving into this area. Much of the following information is adapted from Brody and Nestor, 1980.

A. <u>Winter (November thru February)</u>

Bora winds are common in Venice during wintertime. Winds of 35 knots with occasional gusts to 60 knots are not uncommon. Peak month for Bora occurrence is November while strong winds associated with the Bora can occur in any month. Other strong winds, usually from the south (Scirocco) can occur prior to cold frontal passage associated with a transitory low pressure system from the Gulf of Genoa. Scirocco winds are common in November and December.

Below freezing temperatures occur during winter. Wind chill factors can be dangerous when cold temperatures occur with high winds, common in an intense Bora outbreak. See Table 3-1.

Visibility is generally poor in winter due to fog. Expect about 10 days each month of low (1000 ft) visibilities, especially during early morning hours. On half of those days, the visibility will be near zero for short periods (3 hours), again in the early morning hours, and harbor traffic will cease until visibility improves.

Table 3-1. Wind chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

| Wind Speed | | Cooling Power of Wind expressed as "Equivalent Chill Temperature" | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Knots | MPH | Temperature (°F) | | | | | | | | |
| Calm | Calm | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 |
| | | Equivalent Chill Temperature | | | | | | | | |
| 3-6 | 5 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | -5 |
| 7-10 | 10 | 30 | 20 | 15 | 10 | 5 | 0 | -10 | -15 | -20 |
| 11-15 | 15 | 25 | 15 | 10 | 0 | -5 | -10 | -20 | -25 | -30 |
| 16-19 | 20 | 20 | 10 | 5 | 0 | -10 | -15 | -25 | -30 | -35 |
| 20-23 | 25 | 15 | 10 | 0 | -5 | -15 | -20 | -30 | -35 | -45 |
| 24-28 | 30 | 10 | 5 | 0 | -10 | -20 | -25 | -30 | -40 | -50 |
| 29-32 | 35 | 10 | 5 | -5 | -10 | -20 | -30 | -35 | -40 | -50 |
| 33-36 | 40 | 10 | 0 | -5 | -15 | -20 | -30 | -35 | -45 | -55 |

B. <u>Spring (March through May)</u>

Early spring resembles winter and, as spring progresses, some summer-like days are noted. The strongest Bora episodes usually end by April but milder Boras can occur in any month of the year.

Some visibility restrictions can occur with fog until mid-April. After that, visibility is usually good except for some hazy days when visibility will be 2 to 5 n mi. Wind chill is still a factor during early spring.

C. Summer (June thru September)

The Siberian High is replaced by a large low pressure system extending from Southeast Asia toward Asia Minor. This pressure configuration brings generally warm and dry weather to Venice. When Bora winds do occur, wind speeds are usually less than 25 kt. A west wind, the Garbin, is a summertime phenomena and occurs for short periods (up to six hours) with a maximum intensity of 35 kt. NOTE: The term "Garbin" is also used in Spain and France but denotes a sea breeze. Thunderstorms are most frequent during the summer months but are isolated and usually short-lived.

D. Autumn (October)

The autumn season in the Adriatic is short, lasting only for the month of October and is characterized by an abrupt change to winter-like weather. Both the Bora and the Scirocco winds begin again in October. Visibilities will start to deteriorate during the early morning hours. Wind chill is normally not a factor until late November.

## 3.7 Local Indicators of Hazardous Weather Conditions

There are few local indicators of the Bora. Because the wind is usually dry, there are no cloud patterns occurring at Venice prior to Bora onset. However, there are often clouds atop the mountains to the north before a Bora event. These clouds will have an east-to-west movement which precedes the Bora onset by two or three hours. Another tip-off used by local mariners is that after a solid day of southeasterlies, they expect a Bora wind the next day. Unfortunately, most of the time, when a brisk, cold wind is experienced, the Bora has already started without much

warning. The strongest winds, however, are usually not in the beginning stages of the Bora event so there may be time to take protective measures. Also, there are some general guidelines to use when other than local observations are available.

The following "forecaster hints" are adapted from Brody and Nestor, 1980:

- Expect Bora conditions in the Adriatic Sea when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian Sea, especially from the Gulf of Genoa.

- When Bora conditions are occurring, a well-defined foehn wall cloud over the Dinaric Alps can be seen in satellite imagery. Also, cumulus cloud streaks over the water will indicate gale force (30+ kt) Bora winds are present.

Likewise, there are very few hints available for predicting the onset of a Scirocco. However, the Scirocco's onset is much more gradual than the Bora and it is usually not as intense. One rule, almost foolproof, is that the Scirocco is normally associated with a depression or cyclone which approaches the northern Adriatic Sea from the west or south. Local mariners watch the water level on the "dolphins," vertical timbers lashed together and used as moors, for signs of an oncoming Scirocco. Water will rise one to two hours before the wind and waves come. Waves will usually not build up gradually but come almost with the onset of the wind.

## 3.8 Protective and Mitigating Measures

If at anchorage, with either the Bora or the Scirocco occurring, it is best to protect at sea. High waves (12+ ft) will occur at the anchorage as well as high winds. If berthed, wind effects will be felt more than wave effects. However, it is better to stay berthed as there will be an abnormal amount of small boat traffic as heavy weather approaches.

One maneuver to decrease the effect of the local seas during a severe Bora is to get as close to the eastern Adriatic coastline as possible, in the lee of the high terrain. However, south of Trieste is the Yugoslavian coast with a two n mi territorial limit. The recommended location is to the north of Trieste, moving to within one-half n mi of the coast. Consult charts as there are mussel farms in this area. This maneuver will decrease seas substantially, but may not decrease winds. In fact, it may increase wind speeds, as winds are usually stronger near Trieste than in Venice. This maneuver may best be used, not when in Venice, but when approaching Venice from the southern Adriatic and shelter from the winds is operationally imperative.

## 3.9 Summary of Problems and Actions

Table 3-2 is intended to provide easy to use seasonal references for meteorologists on ships using the port of Venice. Table 2-1 (Section 2) summarizes Table 3-2 and is intended primarily for use by ship captains.

Table 3-2. Potential problem situations at Port of Venice, Italy - ALL SEASONS

| VESSEL LOCATION/SITUATION | POTENTIAL HAZARD | EFFECT - PRECAUTIONARY/EVASIVE ACTIONS | ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD |
|---|---|---|---|
| 1. Moored-inner harbor<br><br>Occurs year-round but most common in cool season. Nov is worst month. | a. ENE'ly winds - Bora<br>Strong winds 35 kt gusting to 60 kt with wave heights to 13 ft common in winter in Venice. | a. Winds, more so than waves, will affect moored ships. Adding lines is most effective measure to take. Wind chill hazards are potentially dangerous in winter and early spring. | a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks over water can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. Strongest during afternoon, weakest at sunrise and sunset. |
| Occurs year-round and peaks during Oct thru Jan. | b. S'LY winds - Scirocco<br>Winds which usually cover the entire Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt gusting to 45 kt are common in winter in Venice. | b. Winds rather than waves will affect moored ships. Scirocco often bring flooding to Venice. During and after flooding, trash and debris float in the canals and can cause fouling of intakes, especially where it concentrates near seawalls. Additional lines may be necessary to protect from high winds. | b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists. Water level in lagoon will rise one to two hours before onset of wind. Note that waves do not build up gradually but will accompany the wind at onset. |
| 2. Anchorage<br><br>Occurs year-round but most common in cool season. Nov is worst month. | a. ENE'ly winds - Bora<br>Strong winds 35 kt gusting to 60 kt with wave heights to 13 ft common in winter in Venice. | a. Winds with wave heights of 13 ft will affect anchored ships and it is usually best to protect at sea during a Bora. It is possible to limit wave heights substantially by maneuvering close to the eastern coastline - north of Trieste. South of Trieste is the Yugoslavian two-mile territorial limit. CAUTION: North of Trieste, there are mussel farms near shore. Consult latest charts. Wind chill factors can be hazardous during winter and early spring. | a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks over water can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. Strongest during afternoon, weakest at sunrise and sunset. |
| Occurs year-round and peaks during Oct thru Jan. | b. S'ly winds - Scirocco<br>Winds which usually cover the entire Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt gusting to 45 kt are common in winter in Venice. | b. Waves often reach 13 ft at the anchorage and it is usually best to protect at sea if possible. Closest protected harbor is Trieste which can afford some protection from waves but not from winds. Widespread fog will often accompany Scirocco winds with near zero visibilities during early morning hours between Oct and mid-Apr. | b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists. Water level in lagoon will rise one to two hours before onset of wind. Note that waves do not build up gradually but will accompany the wind at onset. |

Table 3-2. (Continued)

| VESSEL LOCATION/SITUATION | POTENTIAL HAZARD | EFFECT - PRECAUTIONARY/EVASIVE ACTIONS | ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD |
|---|---|---|---|
| 3. Arriving/Departing<br><br>Occurs year-round but most common in cool season. Nov is worst month. | a. ENE'ly winds - Bora<br>Strong winds 35 kt gusting to 60 kt with wave heights to 13 ft common in winter in Venice. | a. If arriving, it is best to stay at sea until conditions improve. It is possible to limit wave heights substantially by maneuvering close to the eastern coastline north of Trieste. South of Trieste is the Yugoslavian two-mile territorial limit. CAUTION: North of Trieste, there are mussel farms. Consult latest charts. On departure, note that wave heights in the lagoon are minimal but increase sharply once entering the Adriatic. Wind chill factors can be hazardous during winter and early spring. | a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks over water can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. Strongest during afternoon, weakest at sunrise and sunset. |
| Occurs year-round and peaks during Oct thru Jan. | b. S'LY winds - Scirocco<br>Winds which usually cover the entire Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt gusting to 45 kt are common in winter in Venice. | b. It is best to stay at sea if arriving. This is especially true if flooding is occurring in Venice as increased harbor traffic makes navigating hazardous. Fog will often accompany Scirocco winds and harbor traffic ceases when visibility falls below 1000 ft.<br><br>On departure note that wave heights in the lagoon are minimal but increase sharply once entering the Adriatic. | b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists. Water level in lagoon will rise one to two hours before onset of wind. Note that waves do not build up gradually but will accompany the wind at onset. |
| 4. Small Boats<br><br>Occurs year-round but most common in cool season. Nov is worst month. | a. ENE'ly winds - Bora<br>Strong winds 35 kt gusting to 60 kt with wave heights to 13 ft common in winter in Venice. | a. Local water taxis are seaworthy and boating can continue in waves up to 6 or 7 ft. Anchorage is exposed to high winds and waves while the fleet landing is protected from waves. Wind chill factors can be hazardous in winter and early spring. | a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks over water can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. |
| Occurs year-round and peaks during Oct thru Jan. | b. S'ly winds - Scirocco<br>Winds which usually cover the entire Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt gusting to 45 kt are common in winter in Venice. | b. Local water taxis are seaworthy and boating can continue in waves up to 6-7 ft. Anchorage is exposed to high winds and waves while the fleet landing is protected from waves. If flooding is occurring, high water levels may make loading difficult at the landing. During and after flooding, trash and debris can foul boat intakes, especially where it concentrates near seawalls. Often, with a Scirocco, fog will cause reduced visibilities during early morning hours between Oct and mid-Apr. Harbor traffic ceases when visibility falls below 1000 ft. | b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists. Water level in lagoon will rise one to two hours before onset of wind. Note that waves do not build up gradually but will accompany the wind at onset. |

## REFERENCES

Brody, L.R. and M.J.R. Nestor, 1980: Regional Forecasting Aids for the Mediterranean Basin, NAVENVPREDRSCHFAC Technical Report TR 80-10. Naval Environmental Prediction Research Facility, Monterey, CA 93941.

FICEURLANT, 1987: Port Directory for Venice, Italy (1986). Fleet Intelligence Center Europe and Atlantic, Norfolk, Virginia.

Italian Oceanographic Institute, 1982: Surface Currents in Italian Waters, Genoa, Italy.

Kotsch, W.J., 1983: Weather for the Mariner, Third Edition. Naval Institute Press, Annapolis, Maryland.

Robinson, A.R., A. Tomasin and A. Artegiani, 1973: Flooding of Venice, "Quarterly Journal of the Royal Meteorological Society", Volume 99, Bracknell, United Kingdom.

## Port Visit Information

AUGUST, 1987. NEPRF Meteorologists R. Fett and D. Perryman met with the Port Captain and Chief Pilot to obtain much of the information used in this evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and

the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

## A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN-BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period (f = 1/T) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea

surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

## A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end

the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \qquad (1.2)$$

Where v is wind speed in knots and $\bar{T}$ is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \qquad (1.3)$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \qquad (1.4)$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

## A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves)

period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

| Wind Speed (kt) | Minimum Fetch/Duration (n mi) (hrs) | Sig Wave (H1/3 Period/Height (sec) (ft) | Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67) |
|---|---|---|---|
| 10 | 28 / 4 | 4 / 2 | 41 / 55 |
| 15 | 55 / 6 | 6 / 4 | 92 / 123 |
| 20 | 110 / 8 | 8 / 8 | 164 / 220 |
| 25 | 160 / 11 | 9 / 12 | 208 / 278 |
| 30 | 210 / 13 | 11 / 16 | 310 / 415 |
| 35 | 310 / 15 | 13 / 22 | 433 / 580 |
| 40 | 410 / 17 | 15 / 30 | 576 / 772 |

NOTES:

1 Depth throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

2 For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell there wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

## A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

<u>Format:</u> height (feet)/period (seconds)
duration required (hours)

| Fetch Length (n mi) \ Wind Speed (kt) | 18 | 24 | 30 | 36 | 42 |
|---|---|---|---|---|---|
| 10 | 2/3-4<br>1-2 | 3/3-4<br>2 | 3-4/4<br>2 | 4/4-5<br>1-2 | 5/5<br>1-2 |
| 20 | 3/4-5<br>2-3 | 4/4-5<br>3 | 5/5<br>3 | 6/5-6<br>3-4 | 7/5-6<br>3 |
| 30 | 3-4/5<br>3 | 5/5-6<br>4 | 6/6<br>3-4 | 7/6<br>3-4 | 8/6-7<br>3 |
| 40 | 4-5/5-6<br>4-5 | 5/6<br>4 | 6-7/6-7<br>4 | 8/7<br>4 | 9-10/7-8<br>3-4 |
| 100 | 5/6-7[1]<br>5-6 | 9/8<br>8 | 11/9<br>7 | 13/9<br>7 | 15-16/9-10<br>7 |

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

<u>WIND FORECAST OR CONDITION</u>

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

<u>SEA FORECAST OR CONDITION</u>

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in

wind speed or a change in the direction that results in a longer fetch.

## A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

## A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are

considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

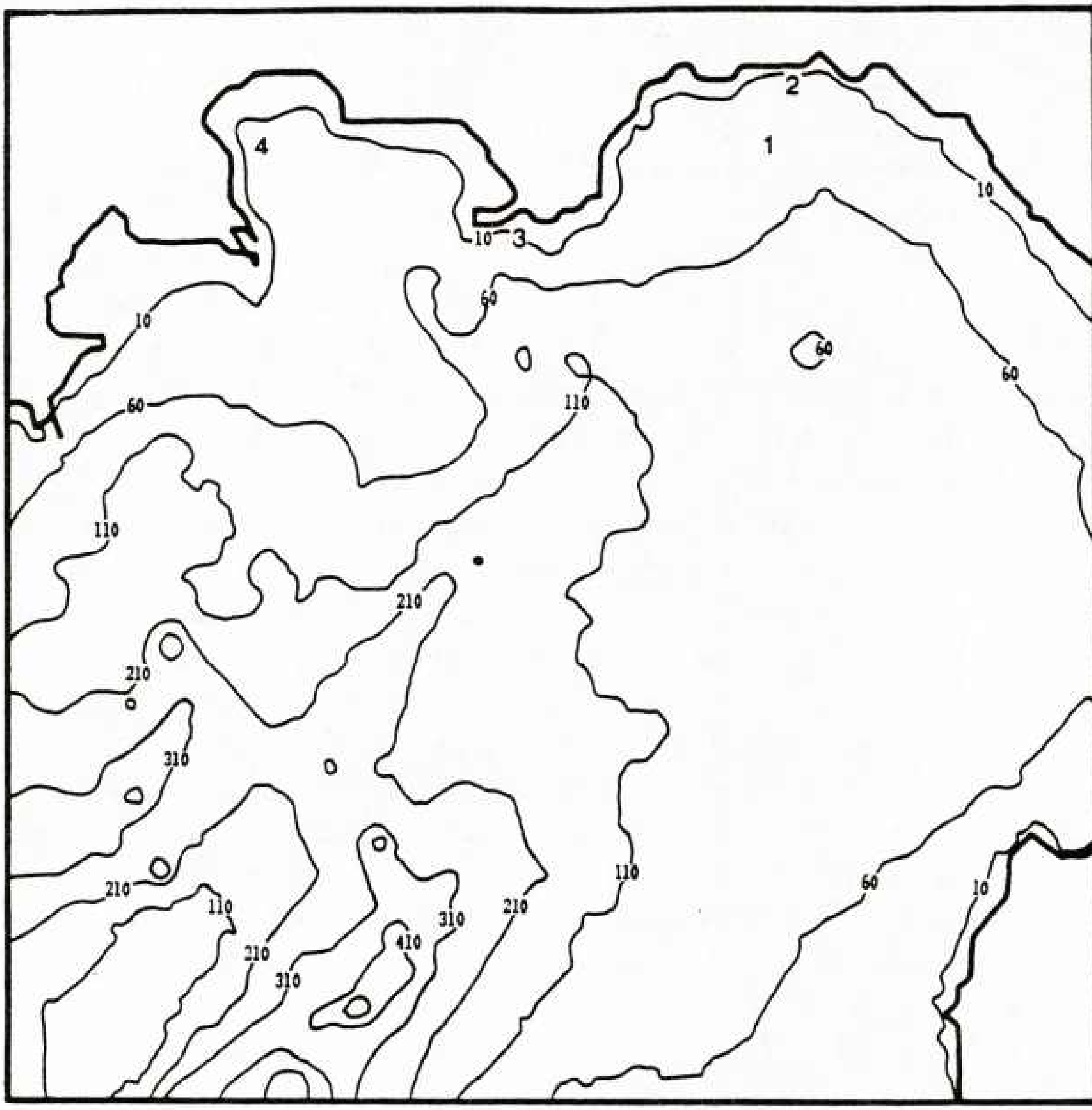


Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathom contour. The larger size numbers identify specific anchorage areas addressed in the harbor study.

## REFERENCES

Hasselmann, K. D., D. B. Ross, P. Muller, and W. Sell, 1976: A parametric wave prediction model. J. Physical Oceanography, Vol. 6, pp. 208-228.

Neumann, G., and W. J. Pierson Jr., 1966: Principles of Physical Oceanography. Prentice-Hall, Englewood Cliffs.

Pierson, W.J. Jr., G. Neumann, and R. W. James, 1955: Practical Methods for Observing and Forecasting Ocean Waves, H.O. Pub. No. 603.

Thornton, E. B., 1986: Unpublished lecture notes for OC 3610, Waves and Surf Forecasting. Naval Postgraduate School, Monterey CA.

U. S. Naval Oceanography Command, 1986: Vol. II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual.

## DISTRIBUTION LIST

SNDL

| | |
|---|---|
| 21A1 | CINCLANTFLT |
| 21A3 | CINCUSNAVEUR |
| 22A1 | COMSECONDFLT |
| 22A3 | COMSIXTHFLT |
| 23B3 | Special Force Commander EUR |
| 24A1 | Naval Air Force Commander LANT |
| 24D1 | Surface Force Commander LANT |
| 24E | Mine Warfare Command |
| 24G1 | Submarine Force Commander LANT |
| 26QQ1 | Special Warfare Group LANT |
| 28A1 | Carrier Group LANT (2) |
| 28B1 | Cruiser-Destroyer Group LANT (2) |
| 28D1 | Destroyer Squadron LANT (2) |
| 28J1 | Service Group and Squadron LANT (2) |
| 28K1 | Submarine Group and Squadron LANT |
| 28L1 | Amphibious Squadron LANT (2) |
| 29A1 | Guided Missile Cruiser LANT |
| 29B1 | Aircraft Carrier LANT |
| 29D1 | Destroyer LANT (DD 931/945 Class) |
| 29E1 | Destroyer LANT (DD 963 Class) |
| 29F1 | Guided Missile Destroyer LANT |
| 29G1 | Guided Missile Frigate (LANT) |
| 29I1 | Frigate LANT (FF 1098) |
| 29J1 | Frigate LANT (FF 1040/1051 Class) |
| 29K1 | Frigate LANT (FF 1052/1077 Class) |
| 29L1 | Frigate LANT (FF 1078/1097 Class) |
| 29N1 | Submarine LANT (SSN) |
| 29Q | Submarine LANT SSBN |
| 29R1 | Battleship Lant (2) |
| 29AA1 | Guided Missile Frigate LANT (FFG 7) |
| 29BB1 | Guided Missile Destroyer (DDG 993) |
| 31A1 | Amphibious Command Ship LANT (2) |
| 31B1 | Amphibious Cargo Ship LANT |
| 31G1 | Amphibious Transport Ship LANT |
| 31H1 | Amphibious Assault Ship LANT (2) |
| 31I1 | Dock Landing Ship LANT |
| 31J1 | Dock Landing Ship LANT |
| 31M1 | Tank Landing Ship LANT |
| 32A1 | Destroyer Tender LANT |
| 32C1 | Ammunition Ship LANT |
| 32G1 | Combat Store Ship LANT |
| 32H1 | Fast Combat Support Ship LANT |
| 32N1 | Oiler LANT |
| 32Q1 | Replenishment Oiler LANT |
| 32S1 | Repair Ship LANT |
| 32X1 | Salvage Ship LANT |
| 32DD1 | Submarine Tender LANT |
| 32EE1 | Submarine Rescue Ship LANT |
| 32KK | Miscellaneous Command Ship |
| 32QQ1 | Salvage and Rescue Ship LANT |
| 32TT | Auxiliary Aircraft Landing Training Ship |

| | |
|---|---|
| 42N1 | Air Anti-Submarine Squadron VS LANT |
| 42P1 | Patrol Wing and Squadron LANT |
| 42BB1 | Helicopter Anti-Submarine Squadron HS LANT |
| 42CC1 | Helicopter Anti-Submarine Squadron Light HSL LANT |
| C40 | Monterey, Naples, Sigonella and Souda Bay only |
| FD2 | Oceanographic Office - COMNAVOCEANCOM |
| FD3 | Fleet Numerical Oceanography Center - FNOC |
| FD4 | Oceanography Center - NAVEASTOCEANCEN |
| FD5 | Oceanography Command Center - COMNAVOCEANCOM |

copy to:

| | |
|---|---|
| 21A2 | CINCPACFLT |
| 22A2 | Fleet Commander PAC |
| 24F | Logistics Command |
| 24H1 | Fleet Training Command LANT |
| 28A2 | Carrier Group PAC (2) |
| 29B2 | Aircraft Carrier PAC (2) |
| 29R2 | Battleships PAC (2) |
| 31A2 | Amphibious Command Ship PAC (2) |
| 31H2 | Amphibious Assault Ship PAC (2) |
| FA2 | Fleet Intelligence Center |
| FC14 | Air Station NAVEUR |
| FD1 | Oceanography Command |
| USDAO | France, Israel, Italy and Spain |

# NAVENVPREDRSCHFAC SUPPLEMENTARY DISTRIBUTION

COMMANDER IN CHIEF
U.S. CENTRAL COMMAND
MACDILL AFB, FL 33608

USCINCENT
ATTN: WEATHER DIV. (CCJ3-W)
MACDILL AFB, FL 33608-7001

ASST. FOR ENV. SCIENCES
ASST. SEC. OF THE NAVY (R&D)
ROOM 5E731, THE PENTAGON
WASHINGTON, DC 20350

CHIEF OF NAVAL RESEARCH (2)
LIBRARY SERVICES, CODE 784
BALLSTON TOWER #1
800 QUINCY ST.
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH
CODE 1122AT, ATMOS. SCIENCES
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH
ENV. SCI. PROGRAM, CODE 112
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH
ATTN: PROGRAM MANAGER, 1122CS
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH
ATTN: HEAD, OCEAN SCIENCES DIV
CODE 1122
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL RESEARCH
CODE 1122 MM, MARINE METEO.
ARLINGTON, VA 22217-5000

OFFICE OF NAVAL TECHNOLOGY
ONR (CODE 22)
800 N. QUINCY ST.
ARLINGTON, VA 22217-5000

CHIEF OF NAVAL OPERATIONS
(OP-006)
U.S. NAVAL OBSERVATORY
WASHINGTON, DC 20390

CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT, OP-986G
WASHINGTON, DC 20350

CHIEF OF NAVAL OPERATIONS
U.S. NAVAL OBSERVATORY
DR. RECHNITZER, OP-952F
34TH & MASS AVE.
WASHINGTON, DC 20390

CHIEF OF NAVAL OPERATIONS
OP-952D
U.S. NAVAL OBSERVATORY
WASHINGTON, DC 20390

CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT, OP-953
WASHINGTON, DC 20350

COMMANDANT OF THE MARINE CORPS
HDQ. U.S. MARINE CORPS
WASHINGTON, DC 20380

OJCS/J3/ESD
THE PENTAGON, ROOM 2B887
WASHINGTON, DC 20301-5000

OFFICER IN CHARGE
NAVOCEANCOMDET
NAVAL EDUCATION & TRNG CENTER
NEWPORT, RI 02841-5000

OFFICER IN CHARGE
U.S. NAVOCEANCOMDET
APO NEW YORK 09406-5000

COMMANDING OFFICER
NAVAL RESEARCH LAB
ATTN: LIBRARY, CODE 2620
WASHINGTON, DC 20390

OFFICE OF NAVAL RESEARCH
SCRIPPS INST. OF OCEANOGRAPHY
LA JOLLA, CA 92037

COMMANDING OFFICER
NORDA
BAY ST. LOUIS
JCSC, MS 39529-5004

COMNAVOCEANCOM
ATTN: CODE N5
BAY ST. LOUIS
JCSC, MS 39529-5000

SUPERINTENDENT
LIBRARY REPORTS
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

CHAIRMAN
OCEANOGRAPHY DEPT.
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

DIRECTOR OF RESEARCH
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

NAVAL POSTGRADUATE SCHOOL
OCEANOGRAPHY DEPT, CODE 68
MONTEREY, CA 93943-5000

LIBRARY
NAVPGSCOL
MONTEREY, CA 93943-5002

PRESIDENT
NAVAL WAR COLLEGE
GEOPHYS. OFFICER, NAVOPS DEPT.
NEWPORT, RI 02841

COMMANDER
NAVAL SAFETY CENTER
NAVAL AIR STATION
NORFOLK, VA 23511

COMSPAWARSYSCOM
ATTN: CAPT. R. PLANTE
CODE 3213, NAVY DEPT.
WASHINTON, DC 20363-5100

COMMANDER, D.W. TAYLOR NAVAL
SHIP RSCH. & DEV. CENTER
SURFACE SHIP DYNAMICS BRANCH
ATTN: S. BALES
BETHESDA, MD 20084-5000

COMMANDER
NAVSURFWEACEN, CODE R42
DR. B. KATZ, WHITE OAKS LAB
SILVER SPRING, MD 20903-5000

DIRECTOR
NAVSURFWEACEN, WHITE OAKS
NAVY SCIENCE ASSIST, PROGRAM
SILVER SPRING, MD 20903-5000

USAFETAC/TS
SCOTT AFB, IL 62225

3350TH TECH. TRNG GROUP
TTGU/2/STOP 623
CHANUTE AFB, IL 61868

OFFICER IN CHARGE
SERVICE SCHOOL COMMAND
DET. CHANUTE/STOP 62
CHANUTE AFB, IL 61868

U.S. ARMY RESEARCH OFFICE
ATTN: GEOPHYSICS DIV.
P.O. BOX 12211
RESEARCH TRIANGLE PARK, NC 27709

COMMANDER
COASTAL ENGINEERING RSCH. CEN
KINGMAN BLDG.
FT. BELVOIR, VA 22060

DIRECTOR
LIBRARY, TECH. INFO. CEN.
ARMY ENG. WATERWAYS STATION
VICKSBURG, MS 39180

DIRECTOR
DTIC, CAMERON STATION
ALEXANDRIA, VA 22314

DIRECTOR, ENV. & LIFE SCI.
OFFICE OF UNDERSEC OF DEFENSE
FOR RSCH & ENG. E&LS
RM. 3D129, THE PENTAGON
WASHINGTON, DC 20505

CENTRAL INTELLIGENCE AGENCY
ATTN: OCR STANDARD DIST.
WASHINGTON, DC 20505

DIRECTOR, TECH. INFORMATION
DEFENSE ADV. RSCH PROJECTS
1400 WILSON BLVD.
ARLINGTON, VA 22209

DEFENSE LOGISTICS STUDIES
INFORMATION EXCHANGE
ARMY LOGISTICS MANAGE. CENTER
FT. LEE, VA 23801

CHIEF, MARINE SCI. SECTION
U.S. COAST GUARD ACADEMY
NEW LONDON, CT 06320

COMMANDING OFFICER
USCG RESTRACEN
YORKTOWN, VA 23690

COMMANDING OFFICER
USCG RSCH & DEV. CENTER
GROTON, CT 06340

NOAA
OCEANOGROAPHIC SERVS. DIV.
6010 EXECUTIVE BLVD.
ROCKVILLE, MD 20852

FEDERAL COORD. FOR METEORO.
SERVS. & SUP. RSCH. (OFCM)
11426 ROCKVILLE PIKE
SUITE 300
ROCKVILLE, MD 20852

NATIONAL CLIMATIC CENTER
ATTN: L. PRESTON D542X2
FEDERAL BLDG. - LIBRARY
ASHEVILLE, NC 28801

DIRECTOR
NATIONAL OCEANO. DATA CENTER
E/OC23, NOAA
WASHINGTON, DC 20235

NOAA RSCH FACILITIES CENTER
P.O. BOX 520197
MIAMI, FL 33152

DIRECTOR
ATLANTIC MARINE CENTER
COAST & GEODETIC SURVEY, NOAA
439 W. YORK ST.
NORFOLK, VA 23510

CHIEF, INTERNATIONAL AFFAIRS
NATIONAL WEATHER SERVICE
8060 13TH STREET
SILVER SPRING, MD 20910

HEAD
OFFICE OF OCEANO. & LIMNOLOGY
SMITHSONIAN INSTITUTION
WASHINGTON, DC 20560

SCRIPPS INSTITUTION OF
OCEANOGRAPHY LIBRARY
DOCUMENTS/REPORTS SECTION
LA JOLLA, CA 92037

SCIENCE APPLICATIONS
INTERNATIONAL CORP. (SAIC)
205 MONTECITO AVE.
MONTEREY, CA 93940

OCEANROUTES, INC.
680 W. MAUDE AVE.
SUNNYVALE, CA 94086-3518

MR W.G. SCHRAMM
WORLD METEOROLOGICAL ORG.
CASE POSTALE #5, CH-1211
GENEVA, SWITZERLAND

DIRECTOR, INSTITUTE OF
PHYSICAL OCEANOGRAPHY
HARALDSGADE 6
2200 COPENHAGEN N.
DENMARK

DIRECTOR OF NAVAL OCEANOGRAPHY
& METEOROLOGY
MINISTRY OF DEFENCE
OLD WAR OFFICE BLDG.
LONDON, S.W.1. ENGLAND

THE BRITISH LIBRARY
SCIENCE REFERENCE LIBRARY (A)
25 SOUTHAMPTON BLDGS.
CHANCERY LANE
LONDON WC2A IAW

MINISTRY OF DEFENCE
NAVY DEPARTMENT
ADMIRALTY RESEARCH LAB
TEDDINGTON, MIDDX ENGLAND

COMMANDER IN CHIEF
ATTN: STAFF METEOROLOGIST &
OCEANOGORAPHY OFFICER
NORTHWOOD, MIDDLESEX HA6 3HP
ENGLAND

LIBRARY, INSTITUTE OF
OCEANOGRAPHIC SCIENCES
ATTN: DIRECTOR
WORMLEY, GODALMING
SURRY GU8 5UB, ENGLAND

METEOROLOGIE NATIONALE
SMM/DOCUMENTATION
2, AVENUE RAPP
75340 PARIS CEDEX 07
FRANCE

SERVICE HYDROGRAPHIQUE ET
OCEANOGRAPHIQUE DE LA MARINE
ESTABLISSEMENT PRINCIPAL
RUE DU CHATELLIER, B.P. 426
29275 - BREST CEDEX, FRANCE

METEOROLOGIE NATIONALE
1 QUAI BRANLY
75, PARIS (7)
FRANCE

DIRECTION DE LA METEOROLOGIE
ATTN: J. DETTWILLER, MN/RE
77 RUE DE SEVRES
92106 BOULOGNE-BILLANCOURT
CEDEX, FRANCE

OZEANOGRAPHISCHE
FORSCHUNGSANTALT BUNDESWEHR
LORNSENSTRASSE 7, KIEL
FEDERAL REPUBLIC OF GERMANY

INSTITUT FUR MEERESKUNDE
AN DER UNIVERSITAT KIEL
DUSTERNBROOKER WEG 20
23 KIEL
FEDERAL REPUBLIC OF GERMANY

INSTITUT FUR MEERESKUNDE DER
UNIVERSITAT HAMBURG
HEIMHUDERSTRASSE 71
2000 HAMBURG 13
FEDERAL REPUBLIC OF GERMANY

DIRECTOR, DEUTSCHES
HYDROGRAPHISCHES INSTITUT=
TAUSCHSTELLE, POSTFACH 220
02000 HAMBURG 4
FEDERAL REPUBLIC OF GERMANY

ISTITUTO UNIVERSITARIO NAVALE
FACILTA DI SCIENZE NAUTICHE
ISTITUTO DI METEOROLGIA E
OCEANOGRAFIA, 80133 NAPOLI -
VIA AMM, ACTON, 38 ITALY

CONSIGLIO NAZIONALE DELLE
RICERCHE
ISTITUTO TALASSOGRAFICO DI
TRIESTE, VIALE R. GESSI 2
34123 TRIESTE, ITALY

DIRECTOR, SACLANT ASW
RESEARCH CENTRE
VIALE SAN BARTOLOMEO, 400
I-19026 LA SPEZIA, ITALY